Appendix E: Directional and Extended-Reach Drilling

Directional drilling is the ability to steer the drill-stem and bit to a desired bottomhole location. Directional wells are initially drilled straight down to a predetermined depth and then gradually curved at one or more different points to penetrate one or more given target reservoirs. This specialized drilling is usually accomplished with the use of a fluid-driven downhole motor (Gerding, 1986), which turns the drill bit. Directional drilling also allows multiple production and injection wells to be drilled from a single surface location such as a gravel pad or offshore production platform, thus minimizing cost and the surface impact of oil and gas drilling, production, and transportation facilities (See Figure E.1). It can be used to reach a target located beneath an environmentally sensitive area and may offer the most economical way to develop offshore oil fields from onshore facilities.

The limitations of directional drilling are primarily dependent upon maximum hole angle, rate of angle change, and torque or friction considerations. In directional drilling, it is now common for the horizontal displacement of the bottom hole location to be twice the vertical depth of the well. That is, a well with a vertical depth of 7,000 feet could have a bottom hole horizontal displacement of 14,000 feet from the drill site. However, in a shallower well, such as one in which a potential target is two miles away from the drill site but only one mile deep, directional drilling would be much more difficult, risky and costly (Schmidt, 1994).

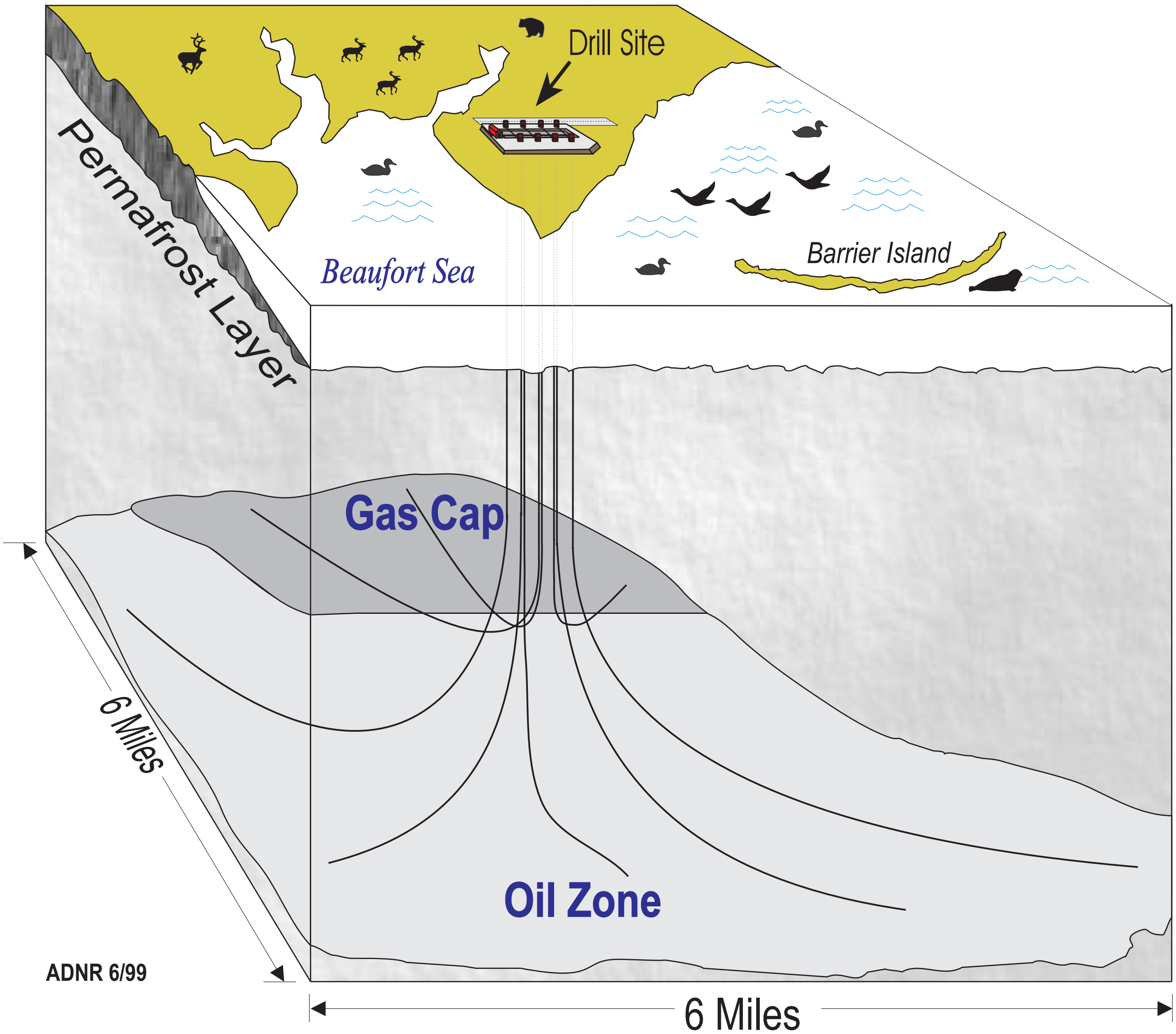
The type of geology or rock that must be drilled in order to reach a target may also limit directional drilling. Coal and shale deposits tend to collapse and cause the drill string to get stuck. This is more likely to happen in wells that take longer to drill and the downhole formations are exposed to the drilling mud and drill string longer. Faults are difficult to track and if a fault is crossed by the drill bit, the type of rock being drilled may suddenly change and a new geologic reference must be established. During this intermediate period in the drilling operation, the driller will not be sure if the desired geologic target was being drilled or could be intersected again (Schmidt, 1994). Stuck pipe can also occur in directional wells when the borehole becomes oval from the drill pipe constantly laying on the downside part of the wellbore. The pipe gets lodged in the groove cut on the bottom of the hole. The most common cause of hole collapse is the chemical difference between in-formation saltwater-and the water in drilling mud. This is especially common when drilling through shale. Ions in the water in the mud have a tendency to transfer to the shale, the shale expands, and small sheets slough off into the hole, causing the pipe to get stuck (Gerding, 1986)

Collisions with neighboring wells can be a problem when drilling multiple boreholes from one surface location. A collision with a producing well could result in a dangerous situation. Anti-collision planning begins with accurate surveys of the subject well and a complete set of plans for existing and proposed oil and gas wells (Schlumberger Anadrill, 1993:55).

Perhaps the greatest limitation on directional drilling is cost. Although directional drilling may be technically possible it is not always economically feasible. Factors such as where the oil or gas deposit is in relation to the drilling rig, the size and depth of the deposit, and the geology of the area, are all important elements in determining whether directional drilling is cost effective (Winfree, 1994). The environment and the cost of multiple pads or locations are also considerations in determining the cost-effectiveness of directional drilling.

FIGURE E.1 Drill Site Block Diagram

Drawing is not to scale.



Horizontal drilling, a more specialized type of directional drilling, allows a single wellbore at the surface to penetrate oil-or gas-bearing reservoir strata at horizontal or near horizontal to the dip of the strata. The wellbore is then open and in communication with the reservoir over much longer distances. In development wells, this can greatly increase production rates of oil and gas or volumes of injected fluids (Winfree, 1994). The fundamentals of drilling horizontal wells can include underbalanced drilling, coiled tubing, bit steering, continuous logging (measurement-while-drilling), multi-lateral horizontals, and horizontal completions. Lateral step-outs are directional wells that branch off a main borehole to access more of the subsurface. Conditions for successful horizontal wells include adequate pre-spud planning, reservoir descriptions, drillable lithologies that will not collapse, and careful cost control (PTTC, 1996).

Extended-Reach Drilling (ERD) has evolved from simple directional drilling to horizontal, lateral, and multi-lateral step-outs (See Figure E.2). ERD employs both directional and horizontal drilling techniques and has the ability to achieve horizontal well departures and total vertical depth-to-deviation ratios beyond the conventional experience of a particular field (Gerding, 1986). ERD can be defined in terms of reach/TVD (total vertical depth) ratios (Judzis, et al., 1997). The definition of an ERD well depends on the results of existing drilling efforts in a particular oilfield (Gerding, 1986). Local ERD capability depends on the extent of experience within specific fields and with specific rigs and mud systems. “ERD wells drilled in specific fields and with specific rigs, equipment, personnel, project teams, etc. do not necessarily imply what may be readily achieved in other areas.” (Judzis, et al., 1997:2).

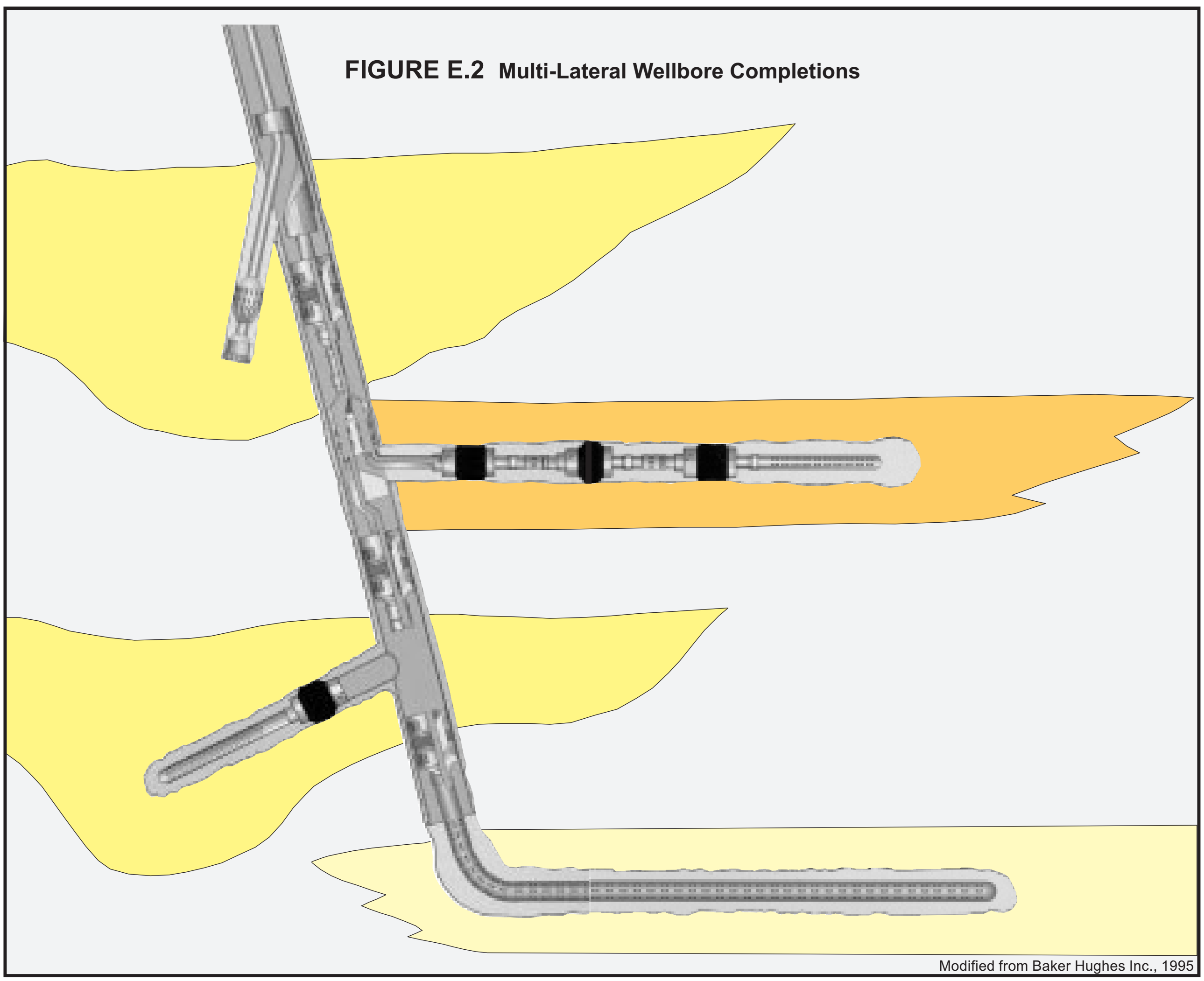


FIGURE E.2 Multi-Lateral Wellbore Completions

Constraints to successful ERD include downhole drill string and casing movement, applying weight to the drill bit, possible buckling of casing or drill string, and running casing successfully to the bottom of the well. Tension may be a primary concern in vertical wells, but in ERD, torsion may be the limiting factor. Running normal-weight drill pipe to apply weight to the bit in ERD can lead to buckling of the drill pipe and rapid fatigue failure. Conventional drilling tools are prone to twist-off, because of unanticipated failure under high torsional and tensile loads of an extended-reach well (JPT, 1994a). Torque can be significantly reduced with the use of non-rotating drill pipe protectors (Payne, et al., 1995). Advanced equipment for an ERD well may include wider diameter drill pipe, additional mud pumps, enhanced solids control, higher capacity top drive, more generated power and oil-based drilling fluids (Judzis, et al., 1997). ERD requires longer hole sections, which requires longer drilling times; the result is increased exposure of destabilizing fluids to the wellbore (JPT, 1994a). The superiority of oil-based muds versus water-based muds in ERD is widely recognized (Payne, et al., 1995). Water-based muds may not provide the inhibition or confining support of oil-based muds (JPT, 1994a).

Extended-reach drill string design involves a) determining expected loads, b) selecting drill string components, c) verifying each component's condition, d) setting operating limits for rig team, and e) monitoring condition during drilling. Economic issues in drill string planning include availability, logistics, and cost. Rig and logistics issues include storage space, setback space, accuracy of load indicators, pump pressure/volume capacity, and top drive output torque. Hole issues include hole cleaning, hole stability, hydraulics, casing wear, and directional objectives (Judzis, et al., 1997).

The working relationship between various components of a drill string must be carefully analyzed. Conventional drill stems are about 30 feet long and are made up of a bit, stabilizer, motor, a measurement-while-drilling (MWD) tool, drill collars, more stabilizers, and jars. There are more than 1,600 parts to a drill string in a 24,000-foot well. A modern drill string can be made up of hundreds of components from more than a dozen vendors. These components may not always perform as anticipated and may not meet operational demands of drilling an extended-reach well (JPT, 1994a).

Successful drilling and completion (casing and cementing) can be curtailed by factors both within and beyond human control. The best available technology may not be used or available due to the pressures of drill program scheduling and the lack of time devoted to seeking the most recent methods or tools. W. L. Penberthy, Jr., a wellbore construction adviser for Baker Hughes Inteq, notes that while the technology exists to complete wells without damaging them, some operators fail. Reasons for failure may include; the operator was in a hurry and didn't recognize that there was a problem; cost and logistical problems; or plans to have the proper fluid system in place in advance of drilling commencement were not made (JPT, 1994b).

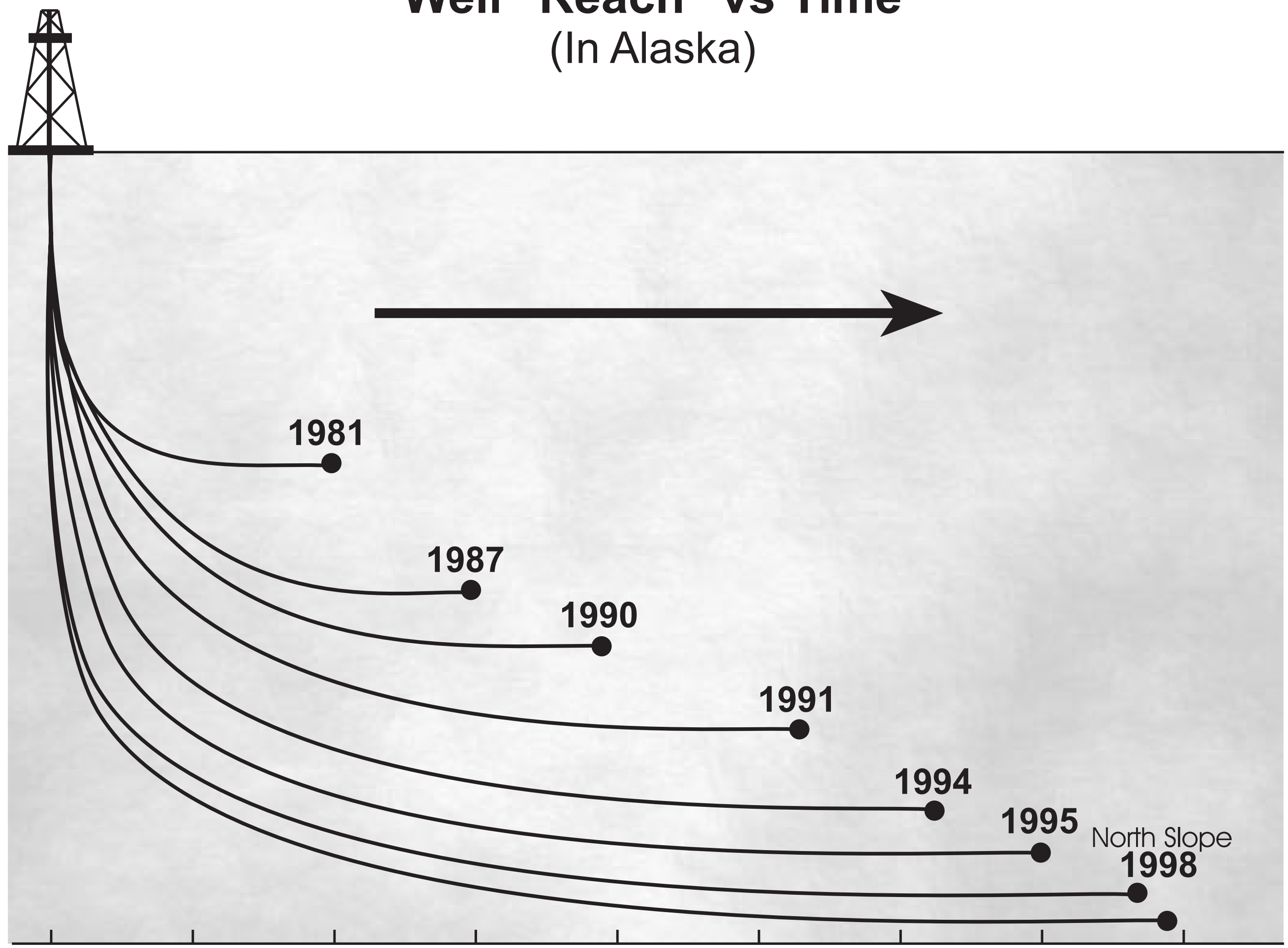
In a few cases, ERD technology has been used instead of platform installation off California, where wells are drilled from onshore locations to reach nearby offshore reserves. ERD has been instrumental in developing offshore reserves of the Sherwood reservoir under Poole Bay from shore at Wytch Farm, U.K. The original development plan called for the construction of a $260 million artificial island in the bay (JPT, 1994a). Other successes with ERD include the North Sea, Gulf of Mexico, South China Sea, and at Milne Point, Badami, Point McIntyre, and Niakuk fields in Alaska (Judzis, et al., 1997).

While a 6.6-mile horizontal displacement was accomplished in 1999 at Cullen Norte 1 well in Argentina (Halliburton, 1999), horizontal displacements (departure from vertical) of one-half mile to two miles are typical. In October of 1998, BP set a long-reach record for horizontal directional wells in the U.S. with a displacement of 19,804 ft. in the Niakuk Field (See Figure E.3). Despite its $6 million price, the well represents a cost saving over the other drilling alternative—construction of an offshore artificial gravel island (AJC, 1996).

It is possible that exploration wells within the sale area may be directionally drilled due to a lack of suitable surface locations directly overlying exploration targets. However, until specific sites and development scenarios are advanced and the specific conditions of drill sites are known, the applicability of directional drilling for oil and gas within the sale area is unknown. Most development wells will be directionally drilled because of the cost savings realized in pad and construction, and in required facilities. Although high departure ERD wells recently have been planned for some new field developments, the most common ERD applications applied to date occur after initial developments have been installed. This is due in part because drilling mechanics and performance are highly variable. Long departure wells show promise in applicability of ERD in Alaska, however equal consideration should be given to local ERD experience and rig capability in assessing the potential for ERD (Judzis, et al., 1997).

Many surface use conflicts can be avoided through directional and ERD. However, some reservoirs are located or sized such that directional drilling cannot eliminate all possible conflicts.

Well "Reach" vs Time
(In Alaska)



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Graphic Not To Scale

FIGURE E.3

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